# NOAA SECTORAL APPLICATIONS RESEARCH PROGRAM (SARP)
## PROJECT ANNUAL REPORT (DRAFT)

**PROJECT TITLE**
**USING NOAA CLIMATE FORECASTS WITH HYDROLOGIC ASSESSMENT TO REDUCE DROUGHT VULNERABILITY AND IMPROVE WATER MANAGEMENT IN WASHINGTON STATE**

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## I. PRELIMINARY MATERIALS

### A Project Abstract

Droughts are the nation's most costly natural disaster. In Washington State, this year's drought inflicted more than $300 million in damage to the agricultural sector, and halved the expected summer runoff that feeds the state economy. State-of-the-art climate forecasts, such as the NOAA CPC seasonal outlooks, offer the potential to mitigate drought damages through advance warning. Yet this potential is largely untapped by water managers; a gap remains between forecast products and their applications, often due to socio-organizational factors. This study will bridge that gap by working directly with users in the transition of NOAA climate forecasts,

coupled with hydrologic assessments, to water resources operations and drought management. Our focus is high stakes and highly drought-vulnerable Yakima River Basin, whose irrigated crops represent the largest agricultural value in the state. Irrigators depend on water from the Yakima Project, operated by the U.S. Bureau of Reclamation (USBR), which issues hydrologic forecasts that could benefit from improved climate information. The PIs will work with USBR to integrate NOAA climate forecast information into short-term and long-term water resources decisions through the UW west-wide streamflow forecasting system. In addition, the system used for the Yakima River basin will extend to the entire state of Washington to improve drought preparedness and response. Here, the PIs will work with the Washington State Department of Ecology (DOE), which has statewide drought decision-making authority, to implement a pilot application in support of the National Integrated Drought Information System (NIDIS), useful to broader efforts of the Western Governors' Association (WGA). Letters of support are provided by USBR and DOE. The work in the Yakima and the State will address these scientific questions, among others: How can NOAA climate forecast products be effectively translated and integrated into decision-making to reduce the vulnerability and impacts of drought? In turn, how can a process of working with stakeholders (e.g., water managers) be developed that will help to promote the integration of forecast information into decision-making? Expected benefits of the project include improved water management and drought mitigation in a key socio-economic sector and throughout Washington State, improved understanding of how to integrate NOAA climate forecast products into water resources decision-making, and a model implementation of climate and hydrologic forecasts in a statewide drought plan and NIDIS application. In addition, because the Yakima River basin exemplifies many water management challenges and conflicts across the U.S., successful transition of NOAA products in this case study is expected to generate broader lessons and national attention.

## B Objective of Research Project

NOAA is increasingly being called upon to demonstrate that its products are useful for decision support purposes. The proposed project addresses this objective by posing the following science and applications questions:

- How can NOAA climate forecast products be effectively translated and integrated into decision-making to reduce the vulnerability and impacts of drought? For instance, how can advanced hydrologic prediction methods, which use state-of-the-art NOAA climate forecasts, result in improved seasonal streamflow forecasts and in turn more efficient water management?
- How can a process of working with stakeholders (e.g., water managers) be developed that will help to promote the integration of forecast information into decision-making? For instance, how can we more effectively bridge the gap between forecasts and their potential beneficial uses, through a process of understanding socio-organizational factors, opportunities and barriers?

We address the above questions by integrating NOAA climate forecast products with advanced hydrologic assessments through an advanced experimental hydrologic forecast system for the western U.S. that incorporates a semi-distributed hydrologic model. A key aspect of this project will be close interaction with our operations partners, and the exploration of advanced forecast products within their operational water management decision process. To do so, we will work directly with the USBR and DOE offices to adapt forecast products into formats that are most useful for their operations. The experience of the PIs is that direct interaction with operations staff in their environment is essential to successful communication of research

products to operations. Therefore, we intend to go well beyond simply providing access to forecast products, and will focus on development of interfaces that will facilitate use of advanced hydrology forecast products into our operations partners' decision process.

C Approach

The primary focus of this research is on integration of NOAA products and research results into water resources decision support. We propose to use NCEP Climate Prediction Center (CPC) 15-day and seasonal climate forecasts and derived hydrologic forecasts in a partnership with two operational water management agencies – the U.S. Bureau of Reclamation, which has operational responsibilities within the Yakima River basin, and the State of Washington Department of Ecology, which has decision authority for the State of Washington. PI Wood will tailor prior and existing research in the UW west-wide hydrologic forecast system to both the State of Washington and the Yakima R. basin focus area, to produce operational Yakima R. basin streamflow forecasts (for input to USBR's water management software) and spatial hydrologic forecasts, and a high resolution State of Washington hydrologic monitoring system.

The user interaction process will follow these general steps (detailed in project proposal), which the PI developed and implemented in previous applications with water managers: 1. Specify Decision Context. 2. Understand Organizational Context. 3. Assess Potential Benefits/Costs. 4. Ensure Project Feasibility. 5. Specify Products. 6. Use Products, Obtain Feedback, Revise. 7. Evaluate Forecasts. The evaluation process will assess the relative benefits/costs of the new information relative to existing information and standard operating procedures. Three operational scenarios for evaluations will be conducted: retrospective, real-time, and prospective. An overall performance goal of the proposed activities is the integration of various NOAA products into the operation, planning, and decision-making activities of our partner agencies. Our success in accomplishing this goal will depend, to a large extent, on successful progress on measures that are coupled with the water management objectives of our user communities. Accordingly, we have developed evaluation measures to track performance in three dimensions: (a) forecast accuracy and decision support performance, (b) user acceptance and organizational assimilation, and (c) research team management.

D Description of any matching funds/activities used in this project

The work draws heavily from previous and ongoing hydrologic modeling and prediction research funded by NOAA (via CPO's CPPA and CDEP programs) and other agencies, this project will focus on transition of these NOAA products and research results to operations, rather than new technological developments. In addition, we have leveraged educational outreach resources provided by the University of Washington Water Center, which the PI directs (see http://depts.washington.edu/cwws/).

## II. ACCOMPLISHMENTS

A. Brief discussion of project timeline and tasks accomplished. Include a discussion of data collected, models developed or augmented, fieldwork undertaken, or analysis and/or evaluation undertaken, workshops held, training or other capacity building activities implemented.

The proposed timeline of the project anticipated the initiation (but not completion) of Tasks 1, 2, 3, 5 and 6 (listed below as CURRENT) by the end of Quarter 3. The future tasks are included below, listed as PENDING.

TASK 1 (CURRENT): **Monitoring**: A statewide drought monitoring system has been implemented using the VIC hydrologic model at 1/16 degree (about 6 km grid mesh). This system provides real-time, daily updating analyses (maps, datasets, and timeseries of hydrologic variables) that characterize hydrologic conditions throughout the state, presented via a website, the preliminary version of which is shown in Figure 1. Figure 2 is an example of a timeseries product from the website that is pertinent to state level monitoring of Water Resources Inventory Areas (WRIAs).

TASK 2 (CURRENT): **Streamflow simulation**: In the focus region of the Yakima River basin, the flow routing network (shown in Figure 3) has been developed and streamflow simulations for 10 of the anticipated 12 locations are being calibrated (Figure 4 shows early results for three locations).

TASK 3 (CURRENT): **Prediction**: Work has begun to prepare the statewide monitoring system with the embedded focus region as the initializing state for 2 week to 1 year lead hydrologic forecasts, from which it will be possible to obtain drought onset and recovery predictions. These will be based on both ensemble streamflow prediction (ESP) techniques advanced by the National Weather Service, and NCEP Climate Prediction Center seasonal outlooks. To this end, the Climate Prediction Center's new consolidated forecast (not previously available to the public) has been obtained and is being evaluated in the Washington State domain. In addition, preliminary work to develop methods for forecast error reduction has resulted in a submitted paper (listed below).

TASK 4 (PENDING): **System evaluation**

TASK 5 (CURRENT): **Decision context specification**. We have conducted meetings with key stakeholders (e.g., federal, state, and regional water officials, irrigation district managers, Yakima River Basin farmers) to understand the current organizational decision processes, current uses of forecast information, needs for NOAA forecast products, barriers to forecast use, and potential net benefits of using the NOAA-CPC forecasts and NOAA-based forecast information developed by this project. We have also identified the specific decisions and decision makers that would use the forecast information. For example: Irrigation district managers need forecast information in January and February (i.e., earlier than they currently receive forecast information, which is the first week of March) in order to make crucial crop management decisions for the upcoming year. Interestingly, irrigation district managers felt that earlier forecasts (i.e., before January) may not be as useful because of the possibility of large snow events during winter.

TASK 6 (CURRENT): **Forecast specification and translation**. Through meetings with stakeholders, we have also started to specify and create the needed forecast information; specifications include the relevant climate/hydrologic indicators, the lead time, the temporal

scale of forecast, spatial scale of forecast, the required skill (including measures of skill relevant to decision-making), the format needed by decision-makers, and the links to impact mitigation. With regard to CPC seasonal forecasts, users expressed difficulties in using and understanding the forecasts (e.g., the interpretation of probabilities, and the accuracy of the forecasts), and our work will be addressing these concerns directly.

TASK 7 (PENDING): **Forecast product use, integration, and refinement**

TASK 8 (PENDING): **Evaluation and communication**

B. Summary of findings

A retrospective evaluation of streamflow forecast performance has indicated that statistical methods must be brought to bear to correct for errors in forecast mean and spread. Existing model based techniques within the National Weather Service River Forecast Centers will gain reliability, hence credibility in the user community, if they begin to incorporate techniques of this type. From the users' perspectives, forecasts need to be tailored to their specific decision needs (i.e., annual crop decisions), and communicated with measures of accuracy and uncertainty that they can understand and trust.

C. List of any reports, papers, publications or presentations arising from this project; please send any reprints of journal articles as they appear in the literature. Indicate whether a paper is formally reviewed and published. *(No text limit)*

**Presentations:**

Shukla, S., D. Alexander, A. Steinemann and A.W. Wood, NOAA Climate Prediction Applications Science Workshop (Seattle), March 2007, Applications of Medium Range To Seasonal/Interannual Climate Forecasts For Water Resources Management In the Yakima River Basin of Washington State

Shukla, S., D. Alexander, A. Steinemann and A.W. Wood, Water Center Annual Review of Research (Seattle), February 2007, Applications of Medium Range To Seasonal/Interannual Climate Forecasts For Water Resources Management In the Yakima River Basin of Washington State

Wood, A., A. Steinemann, D. Alexander and S. Shukla, Fall American Geophysical Union Meeting (San Francisco), Dec 2006, Applications of Medium Range To Seasonal/Interannual Climate Forecasts For Water Resources Management In the Yakima River Basin of Washington State

**Publication:**

Wood, A.W., 2007: Correcting errors in streamflow forecast ensemble mean and spread, *J. of Hydrometeorology* (in review).

D. Discussion of any significant deviations from proposed workplan (e.g., shift in priorities following consultation with program manager, delayed fieldwork due to late arrival of funds, obstacles encountered during the course of the project that have impacted outcome delivery).

E. Where appropriate, describe the climate information products and forecasts considered in your project (both NOAA and non-NOAA); identify any specific feedback on the NOAA products that might be helpful for improvement.

Both climate and hydrologic predictions are being evaluated and utilized in this project. Two primary types of climate information are being used to drive hydrologic forecast ensembles, the streamflow component of which becomes input to water resources system models and decision approaches. Historical climate resampling, the first approach, is inherent in the Ensemble Streamflow Prediction (ESP) method of the National Weather Service River Forecast Centers. The second approach is to use seasonal precipitation and temperature ensembles based on NOAA NCEP Climate Prediction Center's new consolidated seasonal forecast, which underlies their official seasonal outlook. This product represents a more experimental forecasting track that employs NCEP's state of the art techniques in the seasonal to interannual climate forecasting arena.

## III. GRAPHICS: PLEASE INCLUDE THE FOLLOWING GRAPHICS AS ATTACHMENTS TO YOUR REPORT

A. One Power point slide depicting the overall project framework/approach/results to date

B. If appropriate, additional graphic(s) or presentation(s) depicting any key research results thus far
(attached at end)
C. Photographs (if easy to obtain) from fieldwork to depict study information (if applicable).

## IV. WEBSITE ADDRESS FOR FURTHER INFORMATION (IF APPLICABLE)

http://www.hydro.washington.edu/forecast/sarp/

## V. ADDITIONAL RELEVANT INFORMATION NOT COVERED UNDER THE ABOVE CATEGORIES.

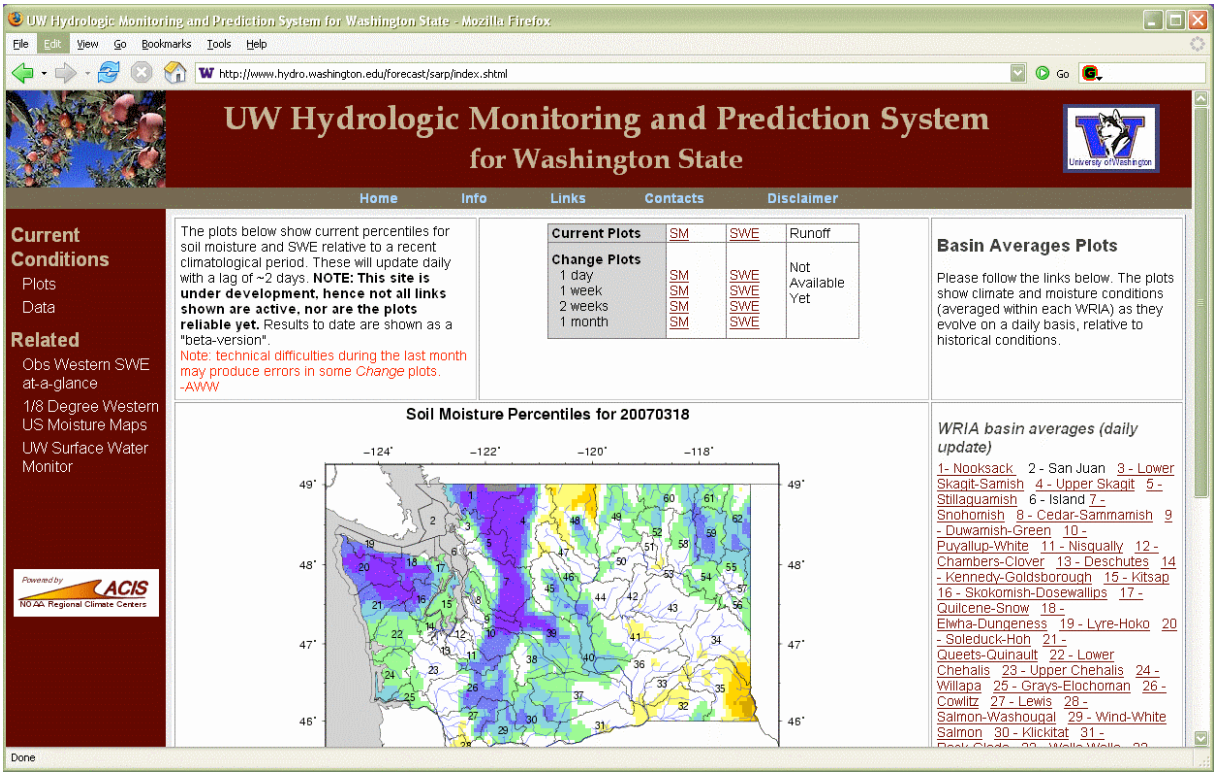


Figure 1: Website for the Washington State hydrologic monitoring system.

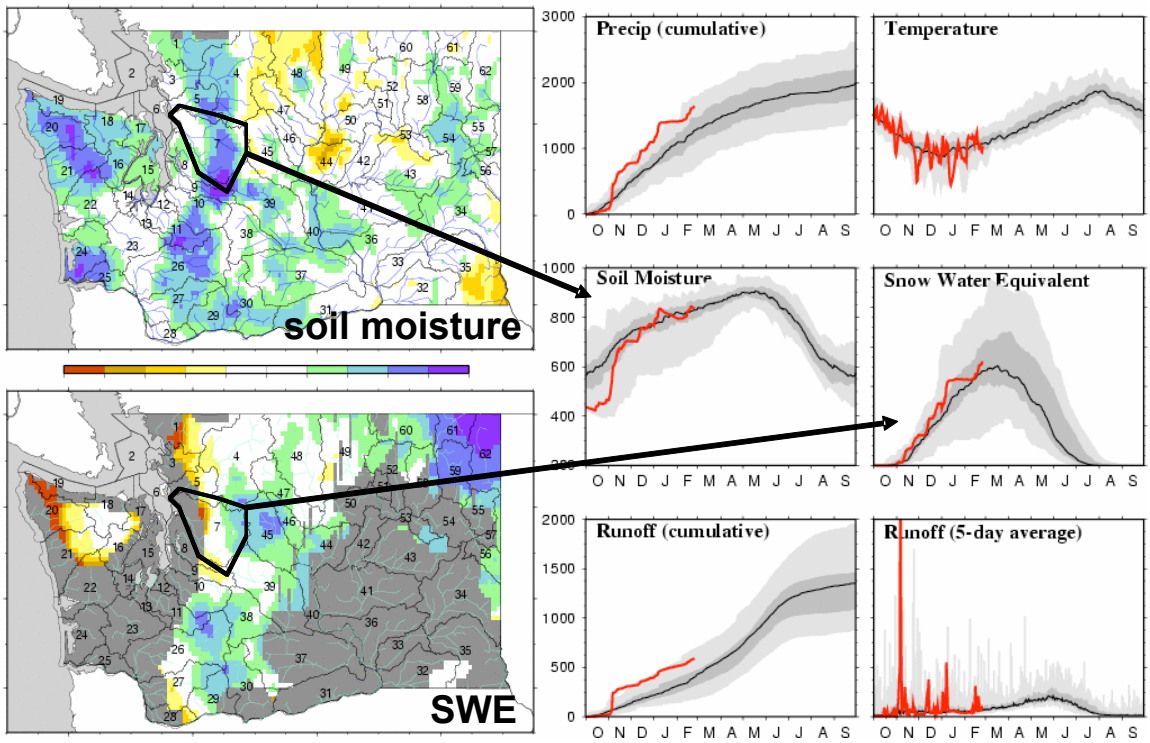


Figure 2: Daily-updating soil moisture and SWE maps for Washington State and associated hydrologic timeseries for each Water Resources Inventory Area.

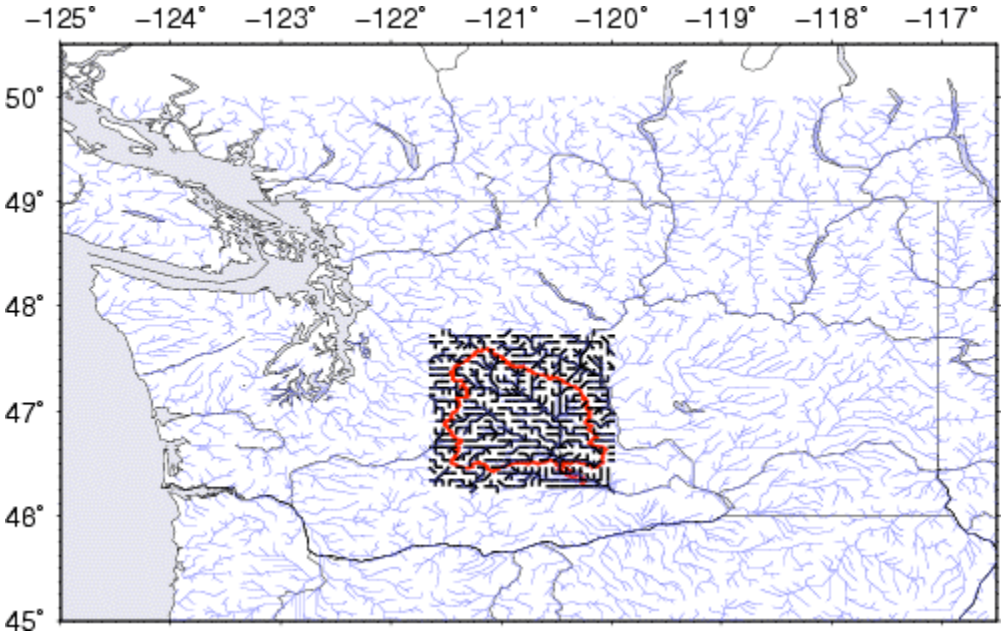


Figure 3: 1/16th degree flow routing network developed for the Yakima River basin focus area within Washington State. The basin's delineation is plotted in red.

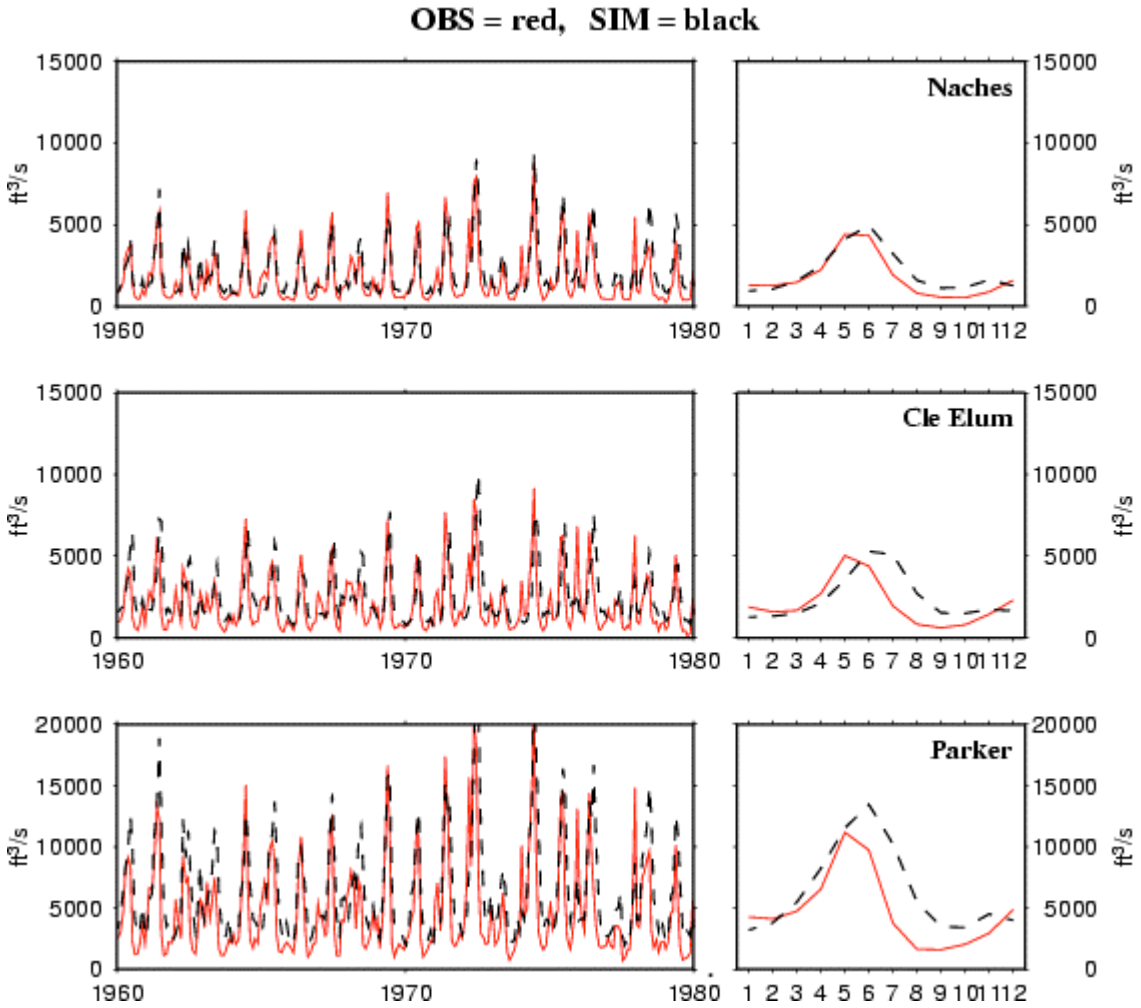

Figure 4: Preliminary calibration results for three streamflow forecast locations in the Yakima River basin (Naches River near Naches, WA; Yakima River at Cle Elum, WA; and Yakima River at Parker, WA).